

ORIGINAL ARTICLE

Two new species and two newly recorded species of Tenuialidae in China, with an updated key to the family (Acari: Oribatida: Gustavioidea)

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Abstract In this work, two new species belonging to the family Tenuialidae from China are described: *Tenuiala hubeiensis* sp. nov., *Hafenrefferia eurycuspis* sp. nov. Two species, *Tenuiala nuda* Ewing, 1913 and *Hafenrefferia gilvipes* (Koch, 1839), are reported for the first time in China. A key is provided for adult identification of the world known species of Tenuialidae. All examined specimens are deposited in the Institute of Entomology, Guizhou University (GUGC), Guiyang, Guizhou.

Key words Tenuialidae, new species, new record, key, China.

1 Introduction

The family Tenuialidae is a small group of Gustavioidea, Oribatida, Sarcoptiformes, which were found plentifully in forest litter in the temperate Holarctic (Norton & Behan-Pelletier, 2009). In 1929, Jacot erected a new subfamily, Tenuialinae under the family Oribatidae, including two genera, *Tenuiala* Ewing, 1913 and *Hafenrefferia* Oudemans, 1906, which were erected based on *Tenuiala nuda* by Ewing (1913) and *Oribates gilvipes* Koch, 1899 as type species by Oudemans (1906), respectively. Then, it was raised to family status (Baker & Wharton, 1952; Woolley & Higgins, 1955). Norton (1983) erected a new subfamily, Peltenuialinae under the family Tenuialidae, which comprises five genera, *Tenuiala*, *Hafenrefferia*, *Hafenrefferia*, *Tenuialoides*, *Peltenuiala*. In the same year, Aoki and Maruyama described a new genus, *Ceratotenuiala*, which was not recorded in Norton's work. Until now, according to Subías (2014), the family Tenuialidae comprises six genera and 14 known species, including a inquirenda species, *Hafenrefferia imperialis* (Berlese, 1910) and *Hafenrefferia lata* Golosova, 1980, which was considered as a synonym of *Peltenuiala orbiculata* (Aoki & Ohnishi, 1974) (Ryabinin & Pankov, 2002). There was only one species—*Hafenrefferia acuta* Aoki, 1966, previously known from China (Chen *et al.*, 2010).

Based on recent survey, some taxa of the family Tenuialidae are identified as new to science or to China. This paper describes two new species, *Tenuiala hubeiensis* sp. nov., *Hafenrefferia eurycuspis* sp. nov., and two newly recorded species in China, *Hafenrefferia gilvipes* (Koch, 1839) and *Tenuiala nuda* Ewing, 1913.

2 Materials and Methods

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Measurements in micrometer (μm) and descriptions are based on adults. Specimens are mounted in temporary cavity slides after clearing in lactic acid, and are studied using a standard light microscope, then stored in 75% alcohol.

The morphological terminology mostly follows Norton (1983) and Norton & Behan-Pelletier (2009). All specimens were deposited in the Institute of Entomology, Guizhou University, Guiyang, China (GUGC).

3 Taxonomy

Hafenrefferia gilvipes (Koch, 1839) New record to China (Figs 1–7)

Oribata gilvioes Koch, 1839: 30.

Hafenrefferia gilvioes: Oudemans, 1917: 29–31, figs 53–57; Sellnick, 1952: 229–232, figs 3–5; Woolley & Higgins, 1955: 53–55, figs 8–9; Aoki & Shimano, 2011: 68–69, fig. E.

Liacarus pterotus Coggi, 1900: 322, fig. 5.

Diagnosis. Lamellae fused together at base of lamellae cusps. Cusps long, narrow, gradually tapering distally. Sensillus somewhat clavate, but pointed at distal end (Fig. 5). Humeral process short, triangular blade-like, with heavily sclerotized medial margins, without marginal serrations (Fig. 1).

Description. General color very dark brown. Integument smooth and shiny. Body length 820–980, width 610–720.

Prodorsum (Figs 1, 3–5). Rostrum deeply notched, lateral teeth pointed, medial one strongly bent ventrally, causing blunt shape in dorsal view; rostral setae (50) inserted behind rostral notches. Tutorium slender, tapering, and exceeded slightly insertion of rostral setae. Lamellae fused together at base of lamellae cusps, so lateral contour of prodorsum visible in dorsal aspect; cusps long, narrow, gradually tapering distally, with two projection on end; lamellar setae (75) inserted terminally in cups. Rostral setae, lamellar setae and interlamellar setae (108) setiform, robust and barbed. Sensillus (94) somewhat clavate, with distal half slightly thickened, but pointed at distal end.

Notogaster (Fig. 1). Notogaster polished and obviously convex. Without visible setae and porosae areae, but with ten pairs of alveoli (*c*, *la*, *lm*, *lp*, *h₁*, *h₂*, *h₃*, *p₁*, *p₂*, *p₃*) and five pairs of lyrifissures (*ia*, *im*, *ih*, *ips*, *ip*). Humeral process short, triangular blade-like, with heavily sclerotized medial margins, no marginal serrations present.

Gnathosoma. Subcapitulum diarthric (Fig. 7), longer than wide. Subcapitulum setae setiform, *h*, *m* and *a* 40, 32, and 33 in length respectively. Chelicerae chelate-dentate.

Ventral region (Fig. 2). Third and fourth epimeral borders united with anterior border of genital opening. Epimeral setal formula: 4-1-3-3. Genital aperture pentagon-shaped, with 6 pairs of setae, anterior two setae longest. 1 pair of aggenital setae present. Anal plates much larger than genital plates, trapezoidal, longer than wide, with 2 pairs of setae. 3 pair of adanal setae present. Lyrifissure *iad* located in front of seta *ad₃*.

Legs. Tridactyle. Chaetotaxy of leg Tr-Fe-Ge-Ti-Ta(famulus included, solenidia in parentheses): leg I 1-5-3(1)-4(2)-20(2); leg II 1-4-3(1)-4(1)-16(2); leg III 2-3-2(1)-3(1)-15; leg IV 1-2-3-3(1)-12.

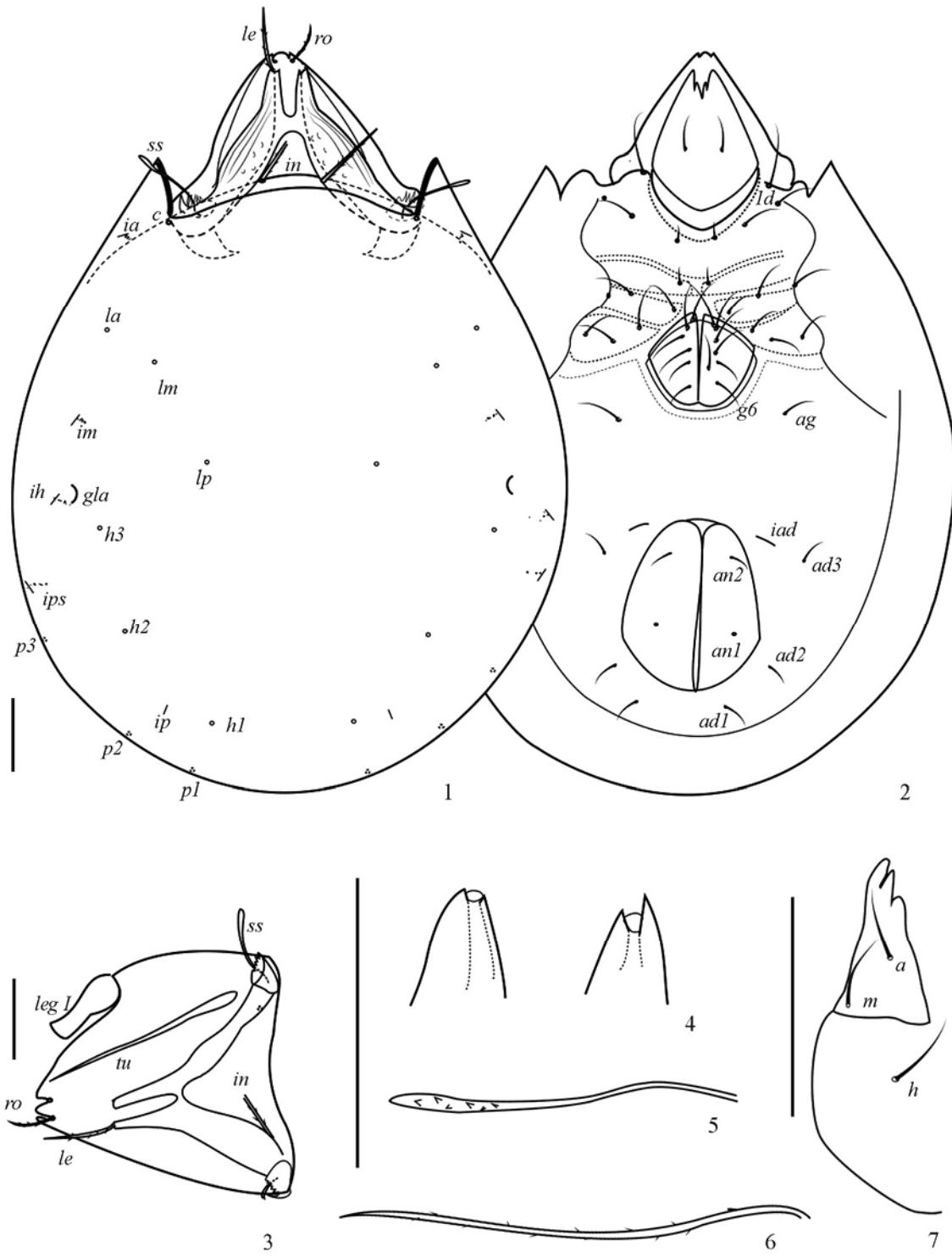
Material examined. 6 adults, China, Heilongjiang, Maoershan Forest Park (45°16'N, 115°23'E), 17 July 2010, Lixia Xie, Daxin Yang and Rong Huang; 15 adults, China, Heilongjiang, Mudanfeng National Nature Reserve (44°27'N, 129°43'E), 19–20 July 2010, Lixia Xie, Daxin Yang and Rong Huang; 5 adults, China, Heilongjiang, Fenling National Nature Reserve (48°07'N, 129°13'E), 22–23 July 2010, Lixia Xie, Daxin Yang and Rong Huang; 2 adults, China, Heilongjiang, Liangshui National Nature Reserve (47°10'N, 128°52'E), 24–26 July 2010, Lixia Xie, Daxin Yang and Rong Huang.

Distribution. China (Heilongjiang), Japan, Russia, Latvia, Czech, Hungary, Italy, Germany.

Remarks. *Hafenrefferia gilvipes* closely resembles to *H. acuta* Aoki, 1966 which had been recorded in China. Aoki (1966) noted that *H. gilvipes* differs from *H. acuta* by the differences of sclerotized median margins of humeral process, projections of lamellar cusps, sensillus and anal aperture. Aoki (1966) indicated that only the outer projection of lamellar cusps of *H. acuta* markedly developed, and the inner one of *H. gilvipes* developed more markedly than outer one. In our materials, the inner one of *H. acuta* developed more markedly than outer one, and the outer one of *H. gilvipes* was longer than the inner one. Anal aperture of our materials also showed no sensible difference between the two species. In our opinion, the principal difference between the two species are as follows: 1) Sensillus of *H. gilvipes* somewhat clavate, with the distal half slightly thickened (Fig. 5), while the latter's sensillus setiform with sparsely ciliate (Fig. 6). 2) Humeral process with heavily sclerotized medial margins in *H. gilvipes*, while in the latter the medial margins of scapular process sclerotized heavily only in its posterior half.

Additionally, *H. gilvipes* is widely distributed in Europe. In China, the species was found only in Heilongjiang Province (Palearctic). *H. acuta* was widely found in China (Heilongjiang, Liaoning, Ganshu, Hebei, Heinan, Shanxi,

Sichuan, Guiyang, Yunnan), encompassed Palearctic and Oriental Regions.



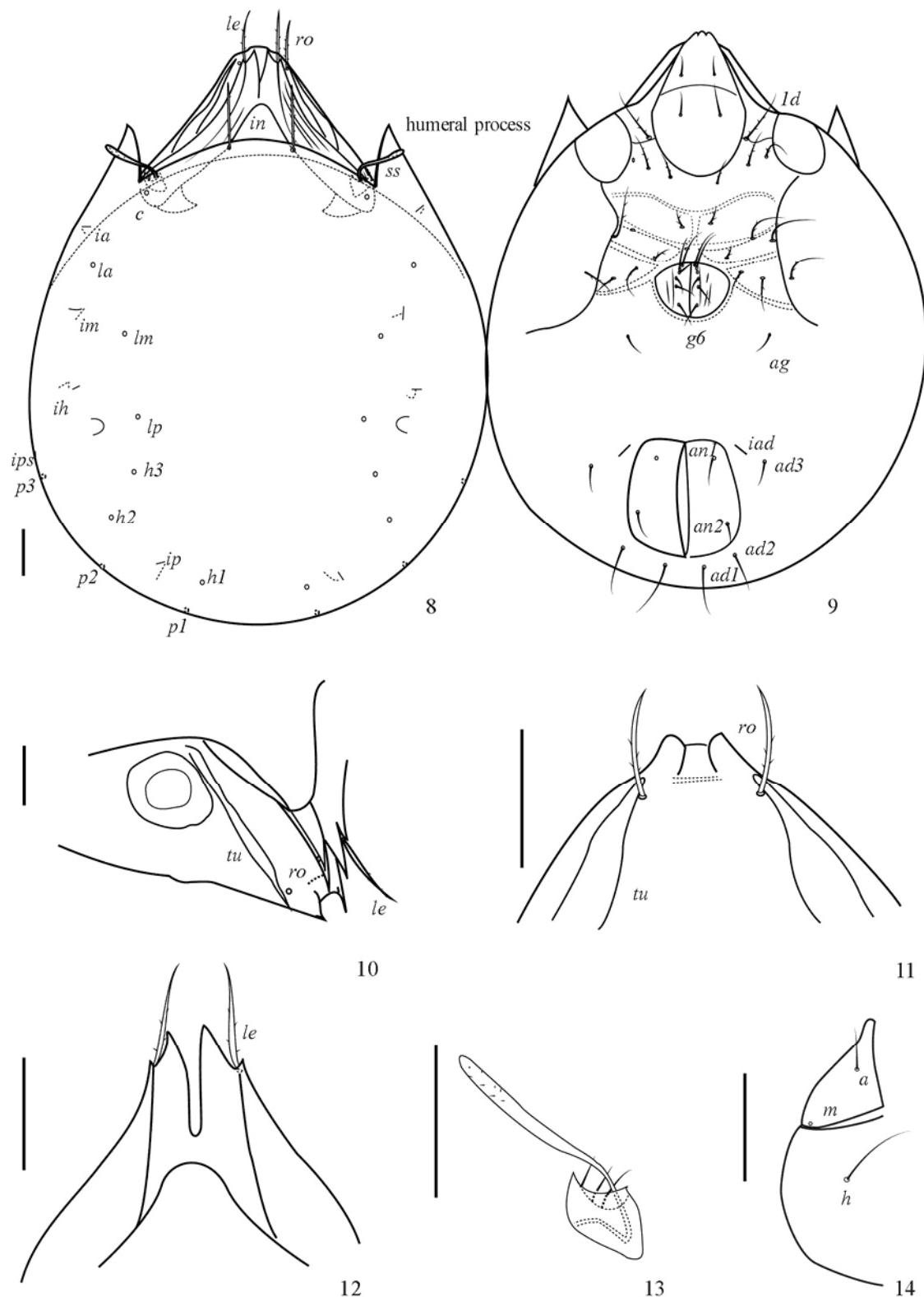
Figures 1–7. *Hafenrefferia gilvipes* (Koch, 1839). 1. Dorsal view. 2. Ventral view. 3. Prodorsum, dorsal-later view. 4. Lamellar cusp, dorsal view, left. 5. Sensillus. 6. Sensillus of *Hafenrefferia acuta* Aoki, 1966. 7. Subcapitulum, ventral view, right half. Scale bars = 100 µm.

Hafenrefferia eurycuspis sp. nov. (Figs 8–14)

Diagnosis. Middle part of rostrum deeply notched, creating two pointed teeth (Fig. 10). Lamellae fused together at base of lamellae cusps. Cusps long, broad, with two projections on end of cusp, inner projection markedly developed (Fig. 12).

Sensillus clavate (Fig. 13). Humeral process short, triangular blade-like, no marginal serrations (Fig. 8).

Description. General color very dark brown. Integument shiny. Large, body length 1290–1350, width 1020–1030.



Figures 8–14. *Hafenrefferia eurycuspis* sp. nov. 8. Dorsal view. 9. Ventral view. 10. Prodorsum, dorsal-later view. 11. Anterior part of prodorsum, dorsal view. 12. Lamellae with cusps and lamellar setae. 13. Sensillus and bothridium. 14. Subcapitulum, ventral view, right half. Scale bars = 100 µm.

Prodorsum (Figs 8, 10–13). Middle part of rostrum deeply notched, creating two sharply teeth. For anterior part of prodorsum steepened, teeth appeared to blunt shape in dorsal view. Rostral setae (73) inserted behind rostral notches. Tutorium slender, tapering, and exceeded slightly insertion of rostral seta. Lamellae fused together at base of lamellae cusps, so lateral contour of prodorsum visible in dorsal aspect. Cusps long, broad, with two projections on end. The inner one was longer than the outer one. Lamellar setae (100) inserted terminally in cups, and in close proximity to the outer projection. Rostral setae<lamellar setae< interlamellar setae (153), setiform and barbed. Sensillus (150) clavate, with distal half slightly barbed.

Notogaster (Fig. 8). Polished and obviously convex. Without visible setae and porosae areae, but with ten pairs of alveoli (*c, la, lm, lp, h₁, h₂, h₃, p₁, p₂, p₃*) and five pairs of lyrifissures (*ia, im, ih, ips, ip*). Humeral process short, triangular blade-like, with heavily sclerotized medial margins, no marginal serrations present.

Gnathosoma. Subcapitulum diarthric (Fig. 14), longer than wide. Subcapitulum setae setiform, *h, m* and *a* 73, 52, and 38 in length respectively. Chelicerae chelate-dentateVentral region (Fig. 9). Epimeral borders distinctly. Third and fourth epimeral borders united with anterior border of genital opening. Taenidium and minitectum of epimeral border IV present, very short. Epimeral setal formula: 4-1-3-3, all setae barbed, seta 1d inserted near corner formed by podecephalic and mentotectum. Genital aperture in the ship of pentagon. 6 pairs of setae, anterior two setae longest. Irregular, longitudinal furrows present on the surface of genital plates. 1 pair of aggenital setae present. Anal plates much larger than genital plates, longer than wide, with 2 pairs of setae. 3 pair of adanal setae present. Lyrifissure *iad* located in front of seta *ad₃*, well removed from anal aperture.

Legs. Tridactyle. Chaetotaxy of leg Tr-Fe-Ge-Ti-Ta (famulus included, solenidia in parentheses): leg I 1-5-3(1)-4(1)-20(2); leg II 1-4-3(1)-4(1)-16(2); leg III 2-3-2(1)-3(1)-15; leg IV 1-2-3-3(1)-12. Femur of leg IV with a narrow ventral blade throughout its length.

Material examined. Holotype China, Shanxi, Taibaishan National Forest Park (33°12'N, 107°89'E; elev. 2280 m), 18 July 2012, Wenqin Liang, Qioxiao Tang. Paratype, 1 adult, same data as holotype.

Etymology. The specific name “*eurycuspis*” refers to broad cusps of lamellae.

Remarks. *Hafenrefferia eurycuspis* sp. nov. mainly differs from *H. acuta* and *H. gilivipes* by following characteristics: 1) Two teeth present on rostrum, the latter two known species have three teeth (Fig. 3). 2) Lamellar cusps long, broad. The other known members of *Hafenrefferia* have narrow, gradually tapering distally (Fig. 1), which is generic diagnosis according to Norton (1983). Though the shape of lamellar cusps of the new species don't conform to the generic diagnosis, the new species and other members of the genus share other generic characters.

Tenuiala nuda Ewing, 1913 New record to China (Figs 15–19)

Tenuiala nuda Ewing, 1913: 133–135, fig.5; Woolley & Higgins, 1955: 46–48, figs 1–2; Norton, 1983: 204; Maruyama & Aoki, 1996: 77–80, figs 1–11.

Diagnosis. Lamellae long and broad, overhung on lateral contour of prodorsum and separated from each other (Fig. 15). Translamella absent. Sensillus lance-shaped (Fig. 18). Humeral processes long, with a long outer tooth and 1–2 minute teeth on anteromedial margins (Fig. 15).

Description. General color a very dark brown. Integument smooth and shiny. Body length 1070–1150; width 940.

Prodorsum (Figs 15, 17–18). Prodorsum steepened at the origin of the cusps. Rostrum emarginate. Rostal setae (63) barbed, shorter than lamellar setae (98). Lamellae long and broad, of equal width throughout their length, overhung lateral contour of prodorsum and separated from each other, without translamella. Lamellar setae strongly curved, barbed, and inserted on ventral surface of cusp; interlamellar setae (100) nearly as long as lamellar setae. Sensillus lance-shaped (130). Tutorium distally broad with tooth, curling slightly and dorsally along the both sides.

Notogaster (Fig. 15). Polished and obviously convex, with 10 pairs of alveoli (*c, la, lm, lp, h₁, h₂, h₃, p₁, p₂, p₃*) and five pairs of lyrifissures (*ia, im, in, ips, ip*). Humeral processes long, with a long outer tooth and 1–2 minute teeth on anteromedial margins.

Gnathosoma. Subcapitulum diarthric (Fig. 19), longer than wide. Subcapitulum setae setiform, *h, m* and *a* 47, 50, and 35 in length respectively. Chelicerae chelate-dentate.

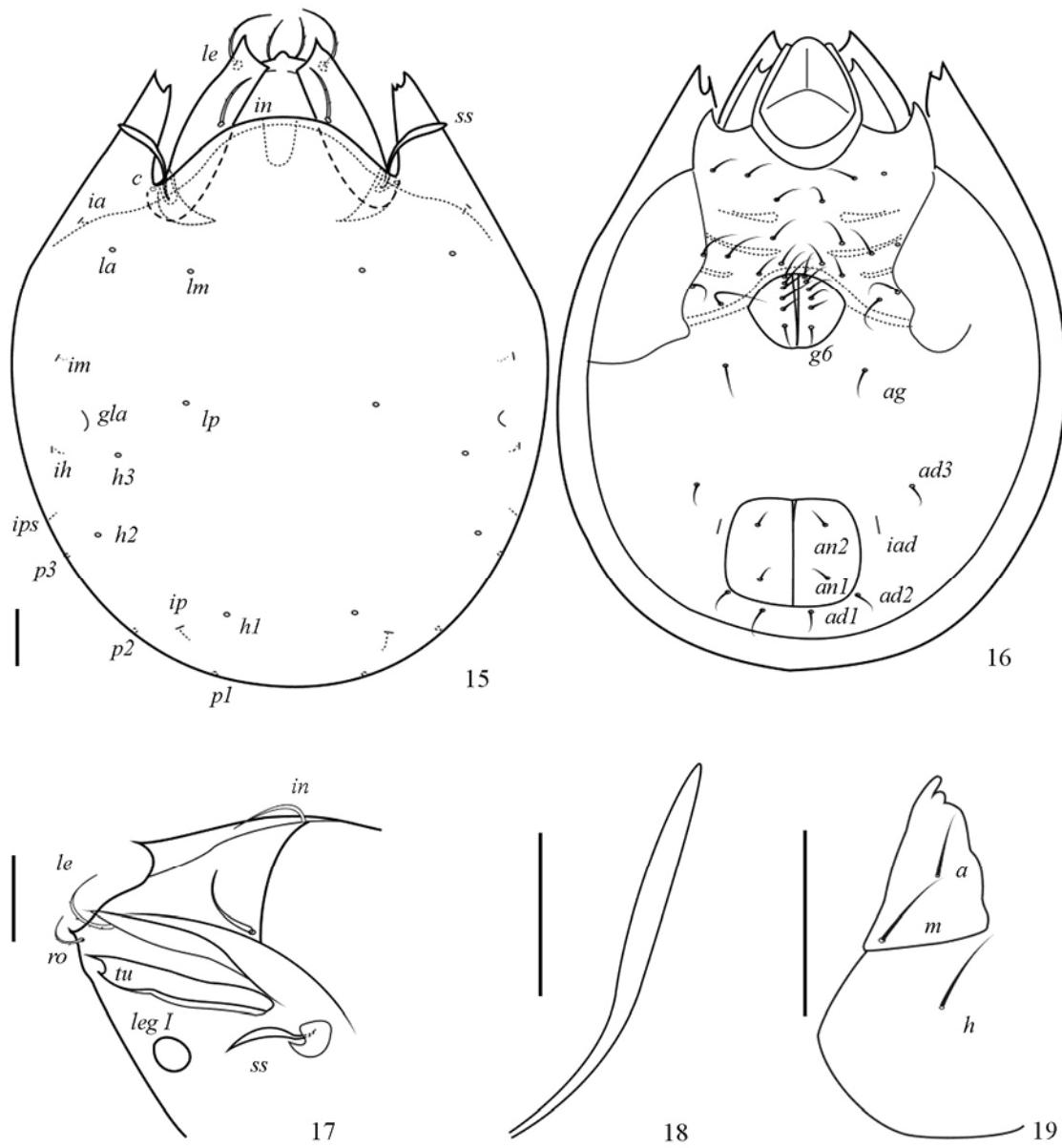
Ventral region (Fig. 16). Third pair of epimeral borders incomplete. Epimeral setal formula: 3-1-3-3. Genital aperture pentagon-shaped, genital plates with 6 pairs of setae, *g₁* and *g₂* were longer than *g₃-g₆*. 1 pair of aggenital setae present. Anal plates much larger than genital plates, rectangular, with 2 pairs of setae. 3 pair of adanal setae present; lyrifissure *iad* located posteriad of *ad₃*, parallel to anal aperture.

Legs. Tridactyle. Chaetotaxy of leg Fe-Ge-Ti-Ta (famulus included, solenidia in parentheses): leg I 5-3(1)-4(2)-20(2); leg II 4-3(1)-4(1)-16(2); leg III 3-2(1)-3(1)-15; leg IV 2-3-3(1)-12.

Material examined. 1 adult, China, Hubei, Triangle Mountain Forest Park ($30^{\circ}29'N$, $115^{\circ}33'E$), 12 July 2010, Wenqin Liang; 1 adult, China, Hubei, Xingdoushan National Nature Reserve ($30^{\circ}14'N$, $108^{\circ}99'E$), 4 August, 2010, Wenqin Liang.

Distribution. China (Hubei), Japan, U.S.A.

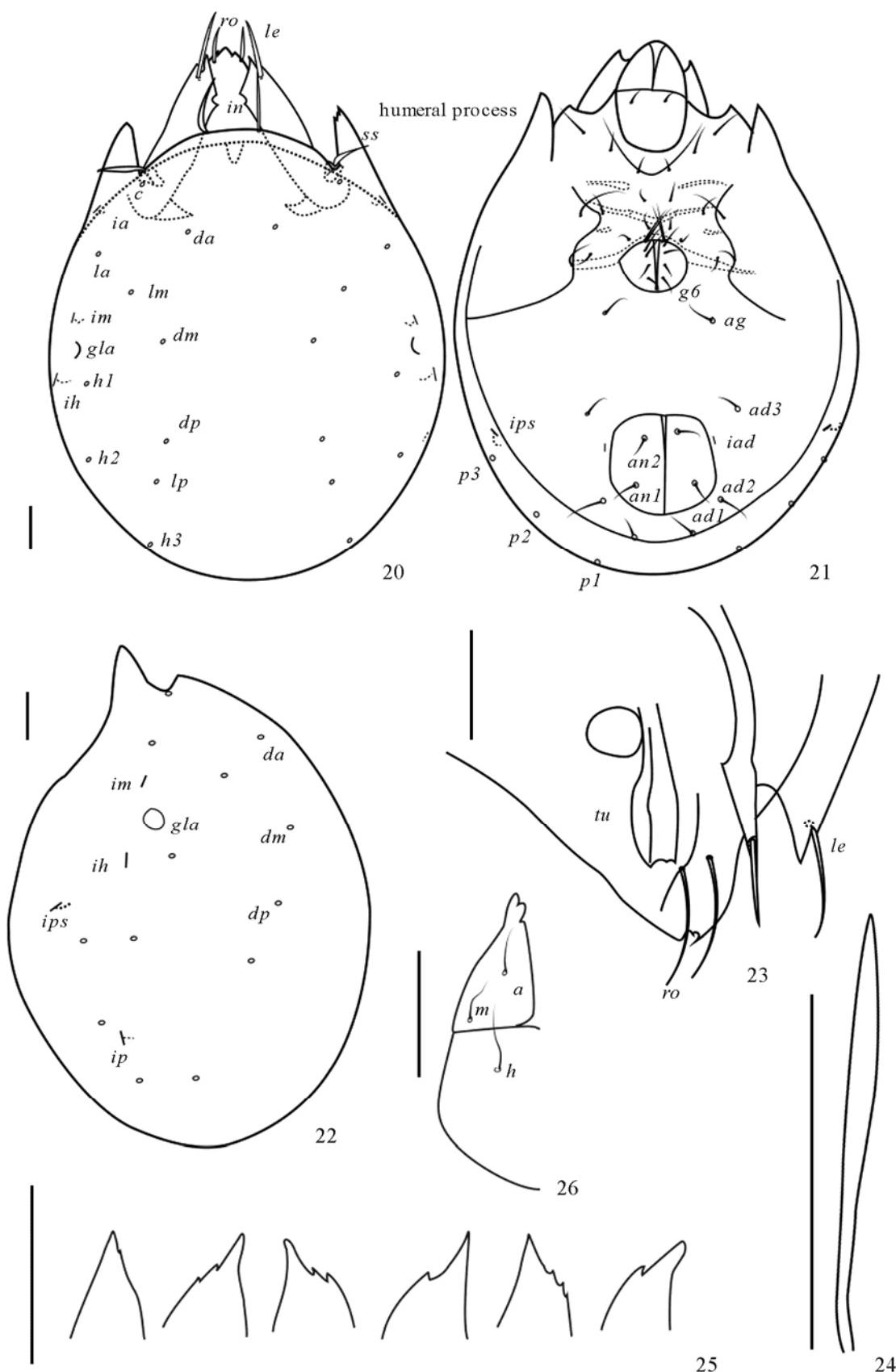
Remarks. The species was redescribed by Maruyama & Aoki (1996), but nogastral lyrifissures were not mentioned in the description. Nogastral lyrifissures were hereby particularly observed and noted. Except differences in chaetotaxy of leg II and leg III, the feature of the specimens from China agreed well with that by Maruyama & Aoki (1996). Maruyama & Aoki (1996) described 14 setae on tarsus of leg II and 13 setae on tarsus of leg III excluding solenidia and famulus. Tarsus of leg II has 16 setae, and tarsus of leg III 15 setae in the examined specimens.



Figures 15–19. *Tenuiala nuda* Ewing 1913. 15. Dorsal view. 16. Ventral view. 17. Prodorsum, dorsal-later view. 18. Sensillus. 19. Subcapitulum, ventral view, right half. Scale bars: 15–17, 19=100 μ m, 18=50 μ m.

Tenuiala hubeiensis sp. nov. (Figs 20–26)

Diagnosis. Rostrum notched, the medial tooth tiny or rounded, two lateral teeth sharply pointed and strongly bent ventrally, causing blunt shape in dorsal view (Fig. 23). Lamellae broad and large, overhung lateral contour of prodorsum in dorsal aspect and separated from each other; notched at the cusp of lamellae, the inner projection markedly developed



Figures 20–26. *Tenuiala hubeiensis* sp. nov. 20. Dorsal view. 21. Ventral view. 22. Lateral view of notogaster. 23. Prodorsum, dorsal-later view. 24. Sensillus. 25. Humeral process. 26. Subcapitulum, ventral view, right half. Scale bars=100 μm.

(Fig. 20). Tutorium distally broad (Fig. 23). Humeral process extended beyond to anteromedial border of notogaster, with marginal serrations (Fig. 25). Notogaster with 13 pairs of setal alveoli (Fig. 20).

Description. General color a very dark brown. Integument shiny. Large, body length 1160–1360, width 860–990.

Prodorsum (Figs 20, 23–24). Anterior part of prodorsum steepened. Notched at rostrum, two lateral teeth sharply pointed and the medial one tiny or rounded in lateral view. Rostral setae (108) inserted behind rostral notches. Lamellae broad and large, overhung lateral contour of prodorsum in dorsal aspect, and separated from each other; cusp of lamellae not reached to the rostral margin, notched to produce two projections, the inner one markedly developed. Lamellar setae (113) inserted at the bottom of notch of lamellar cusp. Rostral setae<lamellar setae< interlamellar setae (135), setiform, sparsely barbed. Sensillus (123) spindlelike, narrow and glabrous. Tutorium distally broad with tooth, didn't extend anteriad of insertion of rostral seta.

Notogaster (Figs 20, 22). Polished, obviously convex. Without visible setae and porosae areae, but with 13 pairs of alveoli (*da*, *dm* and *dp* present) and five pairs of lyrifissures (*ia*, *im*, *ih*, *ips*, *ip*). Humeral process moderately large, extending anteriad beyond to anteromedial border of notogaster, with marginal serrations.

Gnathosoma. Subcapitulum diarthric (Fig. 26), longer than wide. Subcapitulum setae setiform, *h*, *m* and *a* 63, 60, and 38 in length respectively. Chelicerae chelate-dentate.

Ventral region (Fig. 21). Epimeral borders distinctly. Third pair of epimeral borders incomplete and the fourth epimeral borders united with anterior border of genital opening. Epimeral setal formula: 3-1-3-3. Genital plate with 6 pairs of setae, anterior two setae longest. 1 pair of aggenital setae present. Anal plates much larger than genital plates, with 2 pairs of setae. 3 pair of anal setae present. Lyrifissure *iad* located posteriad of level of seta *ad*₃ and adjacent to margin of anal aperture.

Legs. Tridactyle. Chaetotaxy of leg Tr-Fe-Ge-Ti-Ta (famulus included, solenidia in parentheses): leg I 1-5-3(1)-4(2)-20(2); leg II 1-4-3(1)-4(1)-16(2); leg III 2-3-2(1)-3(1)-15; leg IV 1-2-3-3(1)-12. Femur of leg IV with a narrow ventral blade throughout its length.

Material examined. Holotype China, Hubei, Houhe National Nature Reserve (30°04'N, 110°37'E), 28 July 2010, Wenqin Liang. Paratypes. 1 adult, same data as holotype; 1 adult, China, Shanxi, Taibaishan National Forest Park, 22 July 2012, Wenqin Liang, Qiouxiao Tang; 1 adult, China, Sichuan, Luding County, Hailuogou National Forest Park (29°34'N, 101°59'E; elev. 3382 m), 29 July 2012, Wenqin Liang, Qiouxiao Tang.

Etymology. The specific name “*hubeiensis*” is derived from holotype locality

Remarks. *Tenuiala hubeiensis* sp. nov. has 13 pairs of notogastral alveoli present clearly (*da*, *dm* and *dp* present), which is quite different from other known species with 10 pairs of notogastral alveoli in *Tenuiala*.

Key to species of Tenuialidae.

1. Nine pairs of prominent large setae present on notogaster (*Peltenuiala*)..... 2
Only setal alveoli, or one pair of setae (*p1*) present on notogaster 3
2. Lamellae cusps short, subtriangle; Humeral process of notogaster long, reaching anteriad approximately to origin of cusps *Peltenuiala orbiculata* (Aoki & Ohnishi, 1974)
Lamellae cusps elongated and mostly parallel-side; Humeral process of notogaster short, not reaching anteriad as far as origin of cusps *Peltenuiala pacifica* Norton, 1983
3. Lamellae close together, fused basally, cusps bifid at tip, similar in shape to that of *Oribatella* (*Ceratotenuiala*) *Ceratotenuiala echigoensis* Aoki & Maruyama, 1983
Lamellae close together or separated from each other, not similar like *Oribatella* 4
4. Lamellae close enough to each other so lateral contour of prodorsum visibile in dorsal aspect; Tutorium usually gradually narrowing distally 5
Lamellae overhanging lateral contour of prodorsum in dorsal aspect; Tutorium distally broad with corner or tooth 9
5. With a translamella (*Tenuialoides*) 6
Lamellae tuched together at level of cusp origin, without a translamella (*Hafenrefferia*) 7
6. Sensillus with narrow, uniform width except at pointed tip *Tenuialoides medialis* Woolley & Higgins, 1966
Sensillus baciliform, the apical portion being slightly swollen *Tenuialoides fusiformis* Aoki, 1969
7. Lamellar cusps broad, notched at antero-later margins, lamellar setae inserted close to the outer projection of lamellar cusps *Hafenrefferia eurycuspis* sp. nov.
Lamellar cusps narrow, gradually tapering distally 8
8. Sensillus setiform with sparsely ciliate *Hafenrefferia acuta* Aoki, 1966
Sensillus somewhat clavate, with the distal half slightly thickened, but pointed at distal end *Hafenrefferia gilvipes* (Koch, 1839)
9. Humeral process of notogaster without marginal serrations; Without translamella (*Hafenrefferia*) 10
Humeral process of notogaster usually with marginal serrations, if without serrations, translamella present (*Tenuiala*) 11

- | | |
|---|---|
| 10. Lamellar cusps short, subtriangle; Sensillus short, fusiform..... | <i>Hafenferrefia nitidula</i> (Banks, 1906) |
| Lamellar cusps prolonged anteriorly, with a small notch; Sensillus long, somewhat clavate, with the distal half slightly thickened, but pointed at distal end | <i>Hafenferrefia nevesi</i> (Sellnick, 1952) |
| 11. Notogaster with 10 pairs of setal alveoli | 12 |
| Notogaster with 13 pairs of setal alveoli, <i>da</i> , <i>dm</i> and <i>dp</i> present | <i>Tenuiala hubeiensis</i> sp. nov. |
| 12. With translamella | <i>Tenuiala crenulata</i> Woolley & Higgins, 1966 |
| Without translamella | 13 |
| 13. Lamellae separated from each other..... | <i>Tenuiala nuda</i> Ewing, 1913 |
| Lamellae appeared to touched together at base of lamellae cusps..... | <i>Tenuiala kurti</i> Woolley & Higgins, 1955 |

4 Discussion

Norton (1983) proposed the family Tenuialidae and incorporated two subfamilies, Tenuialinae and Peltenuialinae. *Hafenrefferia*, *Tenuialoides*, *Tenuiala*, *Hafenferrefia* belong to Tenuialinae, and *Peltenuiala* belong to Peltenuialinae. In addition, diagnoses were presented for supraspecific taxa. In the same year, Aoki & Maruyama erected *Ceratotenuiala*, which have many diagnosis of Tenuialinae.

According to the species description and illustration of *Hafenferrefia*, *Tenuiala* (Banks, 1906; Ewing, 1913; Woolley & Higgins, 1955; Sellnick, 1952; Woolley & Higgins, 1966; Maruyama & Aoki, 1996), and genera diagnoses presented by Noton (1983), *Hafenferrefia* differs from *Tenuiala* only in having a relatively short scapular (considering *Tenuiala crenulata*), but share many character and synapomorphies. It seems that *Hafenferrefia* may be the synonym of *Tenuiala*, but giving a clear decision need to further study.

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